(1) LEVEL II

RESEARCH NOTE 80-23

DEPARTMENT OF DEFENSE AND SERVICE REQUIREMENTS FOR HUMAN FACTORS R&D IN THE MILITARY SYSTEM ACQUISITION PROCESS

By

Harold E. Price
Marco Fiorello
John C. Lowry
M. Gregory Smith
Jerry S. Kidd

BioTechnology, Inc.
3027 Rosemary Lane
Falls Church, VA

July 1980

DOD HUMAN FACTORS ENGINEERING (HFE) TECHNICAL ADVISORY GROUP (TAG)

Contract MDA 903-79-C-0553

Via

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue
Alexandria, Virginia 22333

Other Supporting Organizations

Air Force Office of Scientific Research Bolling AFB, Washington, DC	**Aerospace Medical Research Laboratory** Dayton, OH	**U.S. Army Human Engineering Laboratory** Aberdeen, MD	**Naval Air Development Center** Warminster, PA

RESEARCH NOTE 80-23

DEPARTMENT OF DEFENSE AND SERVICE REQUIREMENTS FOR HUMAN FACTORS R&D IN THE MILITARY SYSTEM ACQUISITION PROCESS

By

Harold E. Price
Marco Fiorello
John C. Lowry
M. Gregory Smith
Jerry S. Kidd

BioTechnology, Inc.
3027 Rosemary Lane
Falls Church, VA

July 1980

DOD HUMAN FACTORS ENGINEERING (HFE)
TECHNICAL ADVISORY GROUP (TAG)

Contract MDA 903-79-C-0553

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Note 80-23	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DEPARTMENT OF DEFENSE AND SERVICE REQUIREMENTS FOR HUMAN FACTORS IN THE MILITARY SYSTEM ACQUISITION PROCESS		5. TYPE OF REPORT & PERIOD COVERED Final September 1979 - July 1980 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Harold E. Price, Marco Fiorello, John C. Lowry, M. Gregory Smith, and Jerry S. Kidd		8. CONTRACT OR GRANT NUMBER(s) MDA 903-79-C-0553
9. PERFORMING ORGANIZATION NAME AND ADDRESS BioTechnology, Inc. 3027 Rosemary Lane Falls Church, VA 22042		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q162722A765
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Ave., Alexandria, VA 22333		12. REPORT DATE July 1980 13. NUMBER OF PAGES 63
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

This research note is a companion document to ARI Technical Report No. 476, entitled: "The Contribution of Human Factors in Military System Development; Methodological Considerations."

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Human Factors	Human Engineering
Military System Development	Service Regulations
Department of Defense Directives	Service Instructions

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This research note presents a thorough analysis of Department of Defense and service-level policy requirements for human factors in the military system acquisition process. It is intended as a companion document to ARI Technical Report No. 476, and as such provides detailed indoctrination into both the system development process and human factors R&D. It will be particularly useful to those who require a greater understanding of this process.

(continued)

Beginning with an explanation of each system development phase, human factors R&D requirements are then integrated into the system development framework. This is accomplished through direct referral to Department of Defense Directives, Specifications, and Standards. Recognizing that differences occur in Army, Navy, and Air Force implementation of human factors R&D, formal service documentation is presented for human factors in each phase of system development. These documents include service regulations and instructions. Formal service documentation provides only that human factors requirements be implemented, while not setting forth a particular implementation plan. Informal service documentation is presented to illustrate the processes by which human factors is implemented in system development programs initiated by each service.

CONTENTS

	Page
Department of Defense and Service Requirements for Human Factors R&D in the Military System Acquisition Process	1
Overview of the System Acquisition Process	1
Mission Analysis Phase	1
Concept Development Phase	5
Demonstration and Validation Phase	12
Full-Scale Development Phase	15
Production and Deployment Phase	22
Deployment Preparation	22
Retrofit/Improvements	22
Human Factors R&D: DOD Requirements	24
Mission Analysis Phase	24
Concept Development Phase	27
Decision Coordinating Paper	31
Demonstration and Validation Phase	33
MIL-STD-1472B	35
Full-Scale Development Phase	38
Production and Deployment Phase	41
Human Factors R&D: Service Requirements	43
Overall Military System Acquisition Human Factors R&D Requirements	44
Service Requirements for Human Factors R&D in Mission Analysis	46
Service Requirements for Human Factors in Concept Development	47
Service Requirements for Human Factors R&D in the Demonstration and Validation Phase	48
Service Requirements for Human Factors R&D in the Full-Scale Development Phase	50
Service Requirements for Human Factors R&D Through Production and Post-Production Phases	51
Informal Documents	52
Conclusions	55
References	57

EXHIBITS

Exhibit		Page
1	The Phases of the Military's Major System Acquisition Model	2
2	Events During Mission Analysis Phase	3
3	Events During Concept Development Phase	6
4	Events During the Demonstration and Validation Phase	13
5	Events During the Full-Scale Development Phase	16
6	Events During the Production and Deployment Phase	23

DEPARTMENT OF DEFENSE AND SERVICE REQUIREMENTS FOR HUMAN FACTORS R&D IN THE MILITARY SYSTEM ACQUISITION PROCESS

The discussion contained herein provides a detailed expansion of DOD and service requirements for the system acquisition process and for human factors R&D associated with this process. This discussion is meant to support certain sections of an ARI technical report entitled "The Contribution of Human Factors in Military System Development" (Price et al., 1980). Specifically, it supports the summary and review of those topics to be found in the first section of Chapter 3 of that document. This material is recommended especially for those readers who lack confidence in their understanding of the system development process and of the specific efforts involved in each phase (especially as regards human factors R&D).

Overview of the System Acquisition Process

As stated in Chapter 3, DOD directives 5000.1, 5000.2, and 5000.3 provide military implementation procedures for the guidelines and policies outlined in the Office of Management and Budget Circular A-109. The crux of these guidelines and policies is contained in the arrangement of phases within the overall system development cycle. Exhibit 1 depicts an overall military major system acquisition model in order to provide the reader with an overview of the developmental process as it exists today. The following discussion of the model will be on a phase-by-phase basis, to be followed by an integration of the basis for human factors R&D (HF R&D) at both the DOD and service level, with the system development process as outlined.

Mission Analysis Phase

1. Military and Political Changes. R&D. Events during the Mission Analysis Phase are shown in Exhibit 2. In this

Exhibit 1

The Phases of the Military's Major System Acquisition Model

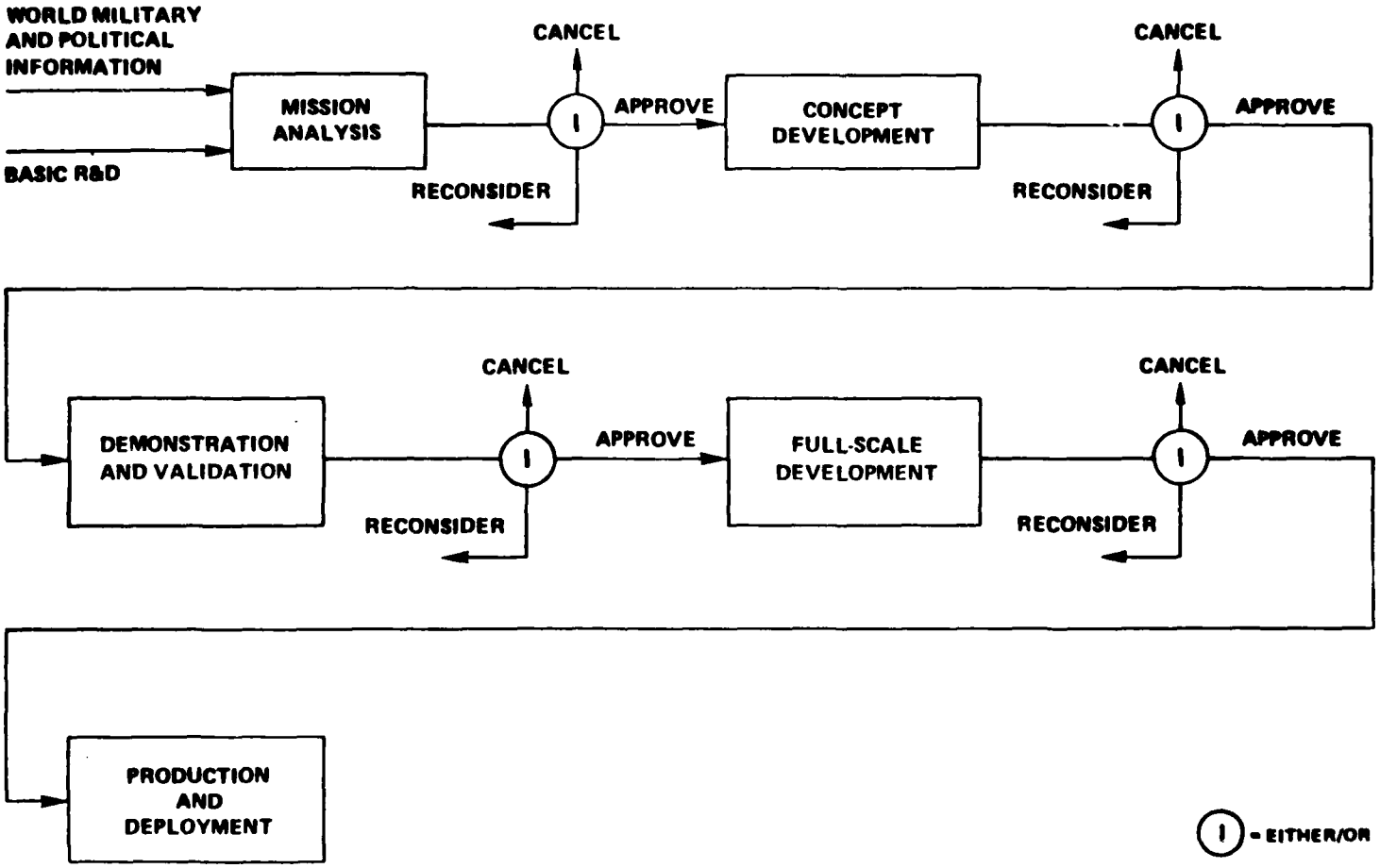
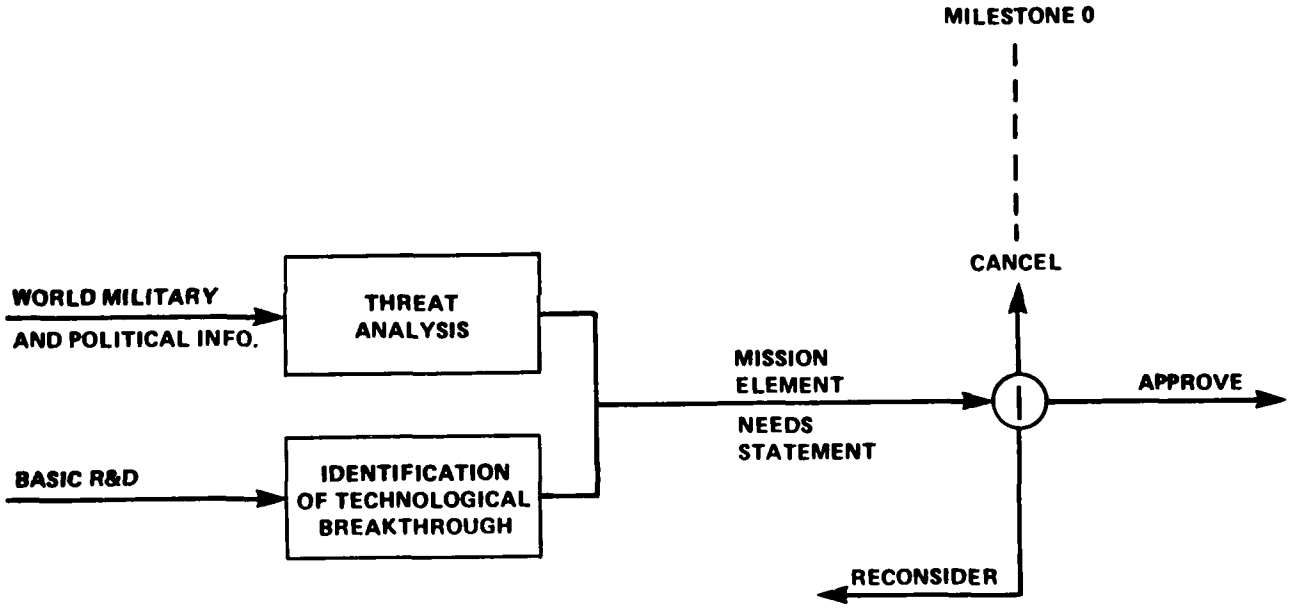


Exhibit 2

Events During Mission Analysis Phase



phase the DOD Component Head (Secretary of the Army, Navy, or Air Force) is responsible for maintaining basic research and development programs to help support future system needs. However, the identification of technological breakthroughs can come from research by government sponsored laboratories, the private sector, or universities.

The other major activity in this phase is threat analysis. The analyses are conducted on world military and political changes. When a serious threat or a technological breakthrough has been identified by the Secretary of Defense (SECDEF) or a DOD Component Head, the DOD Component Head submits a Mission Element Need Statement (MENS) to the Secretary of Defense.

2. MENS. The MENS should describe the mission, how the mission is to be supported, and provide justification for initiation of a new major system acquisition. Specifically, Directive 5000.2 (paragraph C.1) states that the MENS shall:

- Identify the mission area and state the need in terms of the mission element task to be performed. The mission need shall not be stated in terms of capabilities and characteristics of a hardware or software system.

- Assess the projected threat through the time frame the capability is required.

- Identify the existing DOD capability to accomplish the mission.

- Assess the need in terms of a deficiency in the existing capability, a projected physical obsolescence, or a technological or cost savings opportunity.

- State the known constraints to apply to any acceptable solution including operational and logistics considerations, requirements for NATO standardization or interoperability, limits on the resource investment to be made, timing, etc. These constraints will constitute boundary conditions for the exploration of alternative solutions.

- Assess the impact of not acquiring or maintaining the capability.

- Provide a program plan to identify and explore competitive alternative systems extending through to the next Milestone decision. Include the planning to establish a system program office.

After the MENS has been drawn up, it is submitted to the Secretary of Defense for approval for concept development.

3. Milestone 0. If the Secretary of Defense gives approval at Milestone 0, concept development is begun and alternative solutions to the mission need are explored.

Concept Development Phase

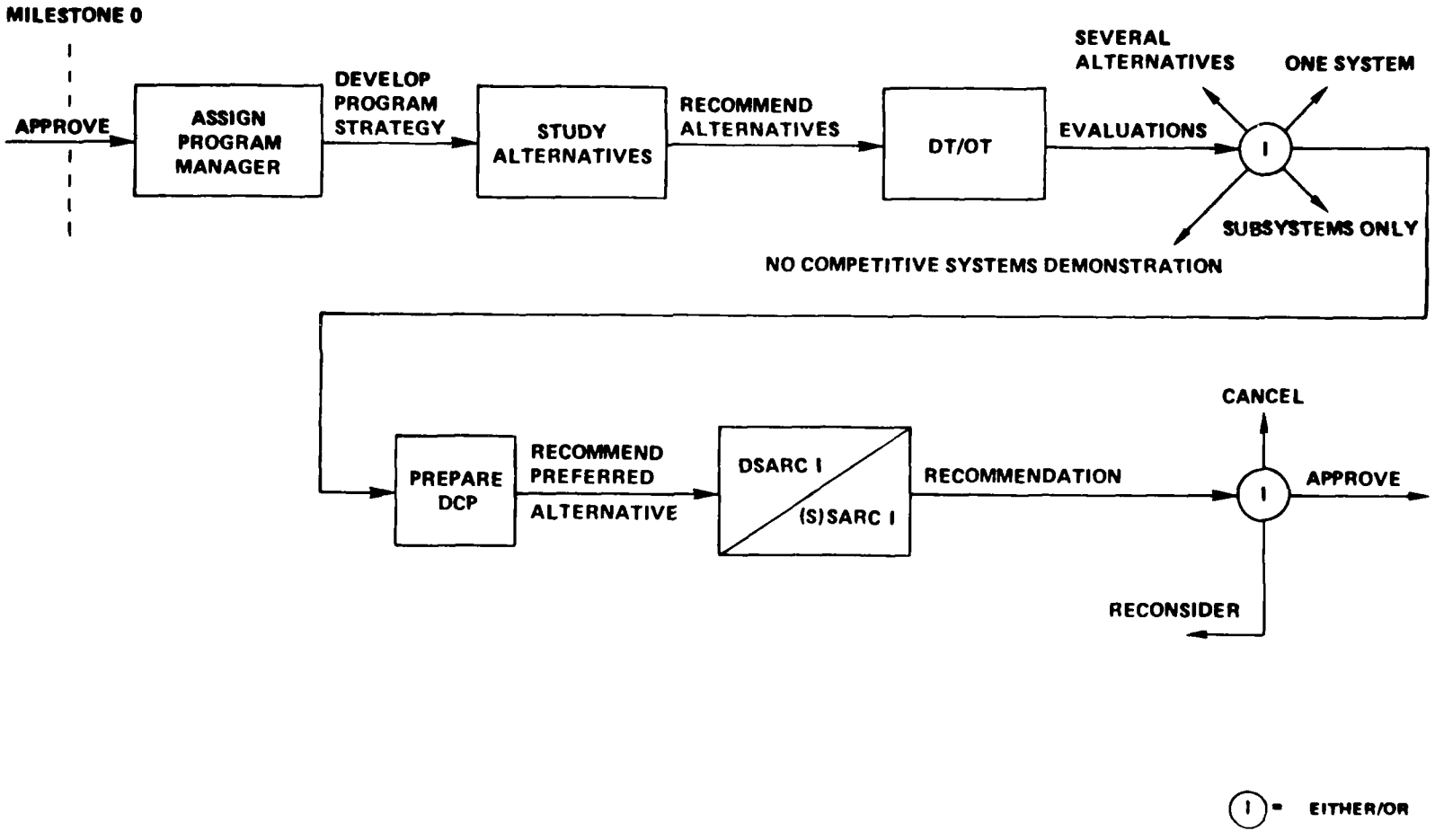
The events in the Concept Development Phase are shown in Exhibit 3. A discussion of these events follows.

1. Program Manager. If the program is approved, the DOD Component Head assigns a Program Manager to achieve the program objectives. No change of Program Managers should occur prior to Milestone 1.

Directive 5000.2 states that the Program Manager shall:

Exhibit 3

Events During Concept Development Phase



- Develop an acquisition strategy for the total program.

- Make maximum use of competition for achieving program objectives.

- Make tradeoff decisions in system capability, cost, schedule, and risk within stated ranges as limited by threshold values. Program management includes the responsibility to determine whether a program should be continued or terminated and to recommend the appropriate action.

- Make every effort to prevent the expenditure of resources to achieve unnecessary performance and schedule requirements. Meaningful relationships shall be established among need, urgency, risk, and worth to allow practical tradeoffs among system capability, cost, and schedule. The Program Manager shall take positive action to continually assess program risk areas and to make or propose tradeoffs in performance, cost, and schedule to achieve the best balance.

The Program Manager assembles a team to consider alternative ways to meet the mission need. The team carries out studies on the alternatives to determine their feasibility, effectiveness, cost of ownership, etc.

The hardware in this phase is in breadboard configurations. These experimental prototypes are built to determine whether the engineering concept(s) is feasible or not.

2. Developmental Test and Evaluation (DT). DT is conducted to verify that technical performance specifications and objectives are being met. Where appropriate, DT includes testing of

components, subsystems hardware/software integration, prototypes, complete systems, and the compatibility with existing or future equipment or systems. In this phase, DT occurs where appropriate to aid in selecting alternative system concepts.

3. Operational Test and Evaluation (OT). OT is conducted to determine a system's effectiveness and suitability. OT is not generally conducted in this phase, but can occur to assess the operational impact of the proposed concepts and to assist in selecting the preferred alternatives.

4. Decision About Alternatives. After studying the alternatives, the DOD Component Head makes a recommendation. That recommendation (based on Directive 5000.2) could be that the next phase, Demonstration and Validation, should:

- involve several alternatives; or
- be limited to a single concept; or
- involve alternative subsystems only and not be conducted at the system level; or
- there should be no competitive systems demonstration, and the program should proceed directly into full-scale development.

5. Decision Coordinating Paper (DCP). After making a decision, a DCP is prepared recommending the preferred alternatives for the next developmental phase. The principal purpose of the DCP is to support the Defense System Acquisition Review Council (DSARC) and the Service Acquisition Review Council ((S)SARC) review and to aid the Secretary of Defense at the decision-making

Milestones. Each service has its own (S)SARC. The Army's council is ASARC; the Navy's NSARC; and the Air Force's AFSARC.

Directive 5000.2 (Enclosure 2, II) states that the DCP will include:

- Update of the MENS.
- Description of the alternative programs, including anticipated performance information.
- A summary of the acquisition strategy.
- Short- and long-term business planning information.
- Program structure and management plan to include security classification guidance.
- Areas of program uncertainty (excluding technical risks) and the probable impact.
- Each DCP prepared for Milestones 1 and 2 shall contain a Technology Assessment Annex (TAA) that will identify any area of technological risk remaining in the program and describe plans for addressing these risks. The TAA shall be prepared by the Program Manager, assisted by a laboratory or laboratories selected for this purpose.
- A resource annex for each program alternative. The annex shall include cost, production, and inventory/ objective data.
- A one-page logistics annex for Milestones 1, 2, and 3.

- DCPs prepared for Milestones 2 and 3 shall contain firm program schedule, cost, and performance information. Program thresholds shall be established for selected performance, cost, and schedule factors representing acceptable, projected variances at program completion and fiscal year thresholds for the same cost and schedule factors to represent acceptable variances at the end of each fiscal year.

- Test and evaluation planning and status.

- Program issues, including their assessment.

- DSARC and (S)SARC results and recommendations.

- Secretary of Defense decisions and direction.

6. DSARC Membership. Directive 5000.2 (Enclosures I, II, and III) states who shall be the members, participants, and advisors of the DSARC. The DSARC members shall be:

- Defense Acquisition Executive (Chairman)
- Director of Defense Research and Engineering
- Assistant Secretary of Defense (Installations and Logistics)
- Assistant Secretary of Defense (Comptroller)
- Assistant Secretary of Defense (Intelligence)
- Director of Planning and Evaluation
- Director of Telecommunications and Command and Control Systems
- Other OSD staff principals when essential to the program under review.

The DSARC participants and advisors shall be:

- Joint Chiefs of Staff representative
- Deputy DDR&E (T&E)
- Chairman of the Cost Analysis Improvement Group
- DOD Component Head.

7. Milestone 1 Issues. DSARC I/(S)SARC I must address the following issues (Directive 5000.2, Enclosure 2, IV.A) for Milestone 1:

- The mission element task to be accomplished is reaffirmed to be essential.
- An updated threat assessment.
- The alternative system design concepts adequately reflect the technology base and provide an acceptable competitive environment.
- Foreign developments have been considered.
- The alternatives recommended for demonstration and validation meet the mission element needs.
- The established program constraints remain valid.
- The projected resource investment for the selected alternatives and other characteristics related to the alternatives are consistent with the stated constraints.
- Operational and logistical considerations are adequate.
- Use of available subsystems and existing military and commercial hardware and software is adequately considered.
- The acquisition strategy is complete, effectively integrates the program technical, business, and management elements, and supports the achievement of program goals and objectives.

- Short- and long-term business planning effectively supports the acquisition strategy.
- Producibility and areas of production risks have been adequately considered.
- Joint-Services, interoperability, and multi-national considerations are adequately treated in the planning.
- NATO standardization and interoperability requirements have been adequately considered.
- Risk and uncertainty areas are identified and adequately treated in the planning.
- Environmental considerations are adequate.
- Planning and schedules for preparation of the Test and Evaluation Master Plan (TEMP) are adequate.
- The program management structure.

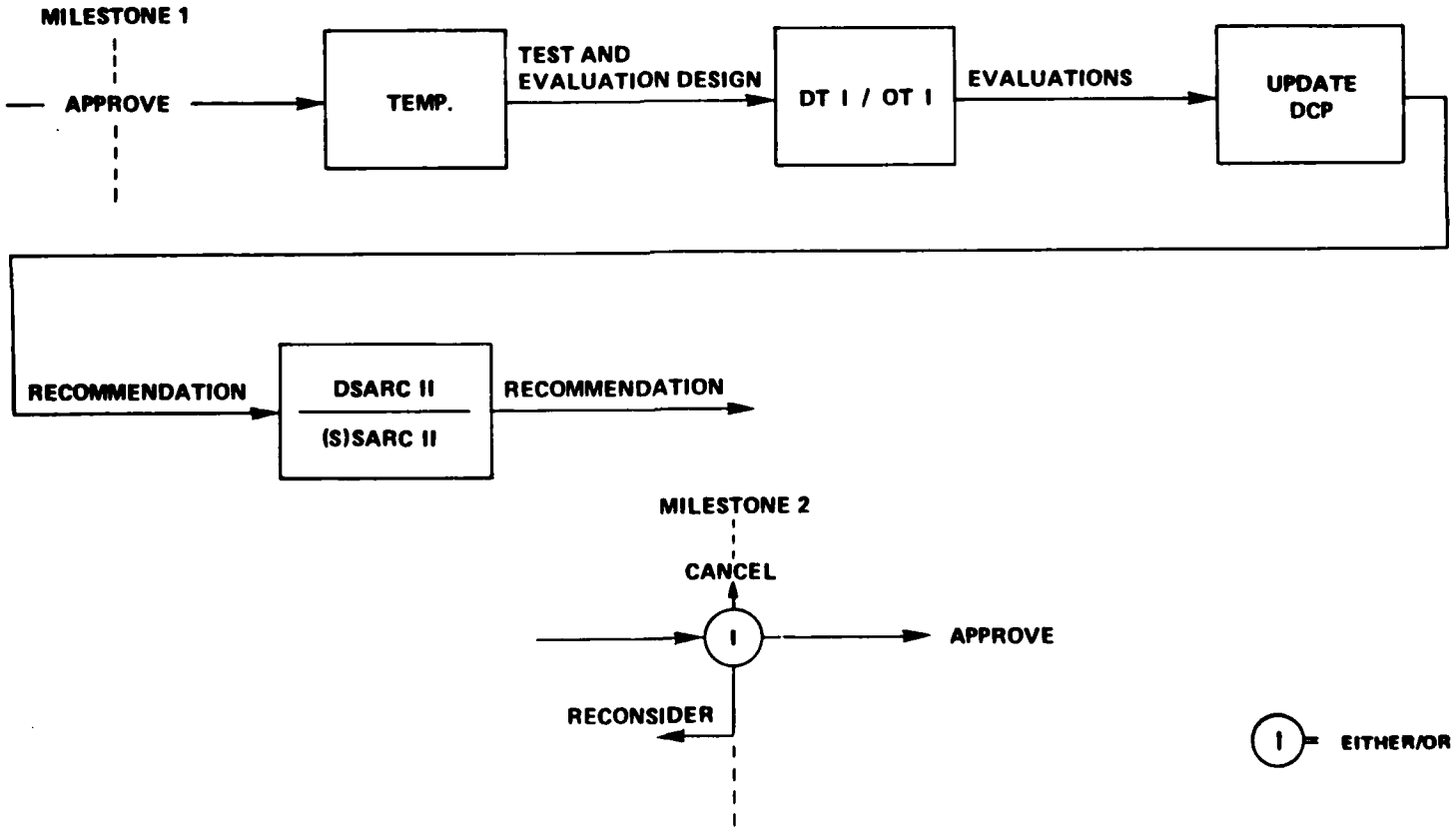
8. Milestone 1. Following the DSARC I/(S)SARC I reviews, the Secretary of Defense is presented one or more alternatives for system demonstration. These recommendations are contained in the DCP. Following the Secretary of Defense review, the Secretary of Defense either concurs in the need for demonstration and validation, sends the program back for further consideration, or cancels the program.

Demonstration and Validation Phase

The events in the Demonstration and Validation Phase are shown in Exhibit 4. Demonstration and validation provide a basis for selection of a system for full-scale development. The demonstrations should be with full-scale prototypes in realistic operating environments. If system demonstrations are not practical or feasible, critical subsystems will undergo competitive demonstrations.

Exhibit 4

Events During the Demonstration and Validation Phase



Because the developing systems will not be adequately defined before the completion of this phase, performance, cost, and schedule estimates are not considered firm prior to the Milestone 2 decision.

1. Test and Evaluation Master Plan (TEMP). An initial version of the overall test and evaluation plan should be prepared as early as possible. An Office of Secretary of Defense-approved TEMP is a prerequisite for Milestone 2. TEMP should identify and integrate objectives, responsibilities, resources, and schedules for all tests and evaluations.

2. Developmental Test and Evaluation I. DT I is conducted to aid in the selection of the preferred technical approach, to show that technical risks have been identified, and to demonstrate that solutions are available.

3. Operational Test and Evaluation I. The first OT is generally conducted in this phase; it is to be conducted in as realistic an environment as possible, so as to provide information about the operational effectiveness and suitability of each of the candidate systems. OT includes gaining information on a system's survivability/vulnerability, transportability, reliability, maintainability, safety, human factors, logistic supportability, and training requirements as well as information on personnel requirements, doctrine, and tactics.

In order not to expend unnecessary resources, any duplicate tests scheduled for DT and OT should be combined into a single test. The test must be coordinated, planned, and executed to provide all needed information to the involved agencies.

In each service, there is an agency charged with the conduct of OT. This agency is separate and distinct from the developing, procuring, or using command. This separate agency is to:

- participate in the planning of those portions of DT that pertain to the accomplishment of OT objectives;
- review the results of DT that pertain to the accomplishment of OT objectives;
- insure that all OTs are effectively planned and conducted; and
- provide to (S)SARC the results of OTs just completed, and the adequacy of planned OTs.

4. Update DCP. After demonstration and validation is completed, the DOD Component Head updates the DCP to recommend one system for full-scale development and production.

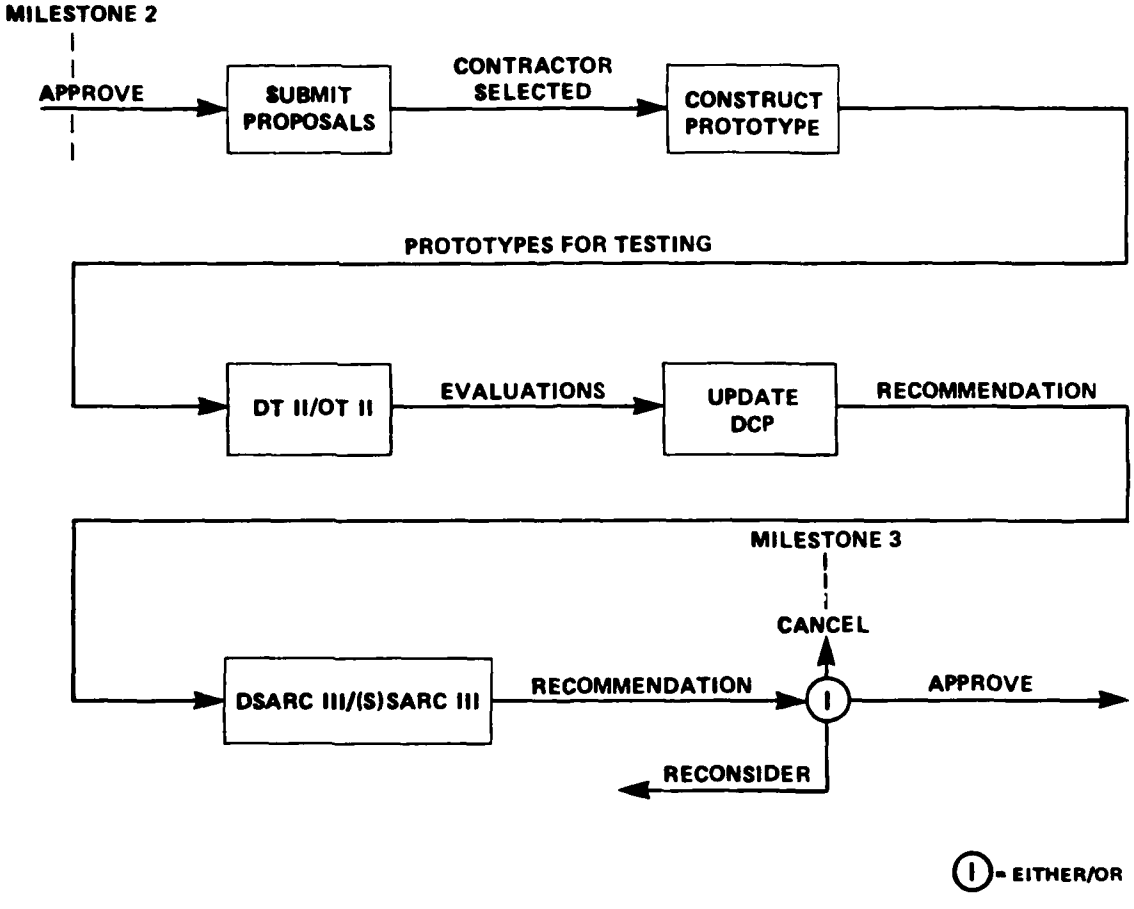
5. Milestone 2. If the program is to continue, the Secretary of Defense approves the selection of a system for full-scale development and the limited production of enough items for operational test and evaluation.

Full-Scale Development Phase

The events for the Full-Scale Development Phase are shown in Exhibit 5. There is to be no change of Program Managers during full-scale development or prior to a Milestone 3 decision. A firm, detailed logistics plan is to be established early in this phase. Subsystems are not to be fully developed until a system has been selected for full-scale development.

Exhibit 5

Events During the Full-Scale Development Phase



1. Proposals and Prototypes. Contractors are required to submit firm proposals for their systems for full-scale development and for initial production items. DOD will supply contractors with the factors, criteria, and conditions to be used in the evaluation and selection of the system. Contractors are to tailor the standards and specifications to the particular system under development. Firm acquisition and ownership costs are to be established. After being selected, the contractor proceeds with the building of the prototype(s) for DT/OT testing.

The DCP for Milestone 1 should contain a Technology Assessment Annex that identifies any area of technological risk that remains in the program and ways to address that risk.

DSARC II/(S)SARC II reviews are to address the following issues for the Milestone 2 decisions (Directive 5000.2, Enclosure 2, IV, B):

- The mission element task to be accomplished is reaffirmed and the threat updated.
- The system selected meets the mission element needs, is cost-effective, and is acceptable within stated constraints.
- NATO standardization and interoperability requirements are satisfied.
- The demonstration and validation results support the system recommended.
- System tradeoffs have produced the most effective balance in cost, performance, and schedule, including operational and logistical considerations.

- Uncertainties and risks have been identified and are acceptable; planning to resolve the remaining uncertainties and risks is adequate. Realistic fall-back actions and alternatives have been established.

- The acquisition strategy has been updated, effectively supports achievement of program objectives, and is being executed in the conduct of program management.

- Short- and long-term business planning supports the strategy. Contract types are consistent with the program characteristics, risks, uncertainty, and strategy.

- Design-to-cost and life cycle cost requirements are realistic and effective in achieving cost objectives.

- Cost, performance, and schedule estimates and related thresholds have been thoroughly reviewed, are well defined, and are consistent with risks involved. These values shall be established as firm estimates.

- Action to submit the initial Selected Acquisition Report (SAR) is complete.

- Planning for selection of major subsystems is clearly stated, provides for sustained competition to the maximum extent feasible, and accepts the use of existing military and commercial hardware and software where appropriate. Foreign developments have been considered.

- Demonstration and validation testing and evaluations have been completed and results support the recommendations.

- Electronic/infrared/optical counter-countermeasure performance requirements have been identified.

- Producibility considerations and areas of production risks have been reviewed and the results found acceptable.

- Requirements have been established for long-lead procurement items and initial limited production to support operational test and evaluation needs for the verification of production engineering and design maturity, and to establish the production base.

- The Test and Evaluation Master Plan (TEMP) identifies and integrates the testing and evaluation to be accomplished prior to the Milestone 2 and 3 program decision points.

- Requisites for the Milestone 3 production and deployment decision including operational and logistical support have been established.

- The program management structure and plan are sound and adequately supported.

2. Developmental Test and Evaluation II. Adequate developmental testing and evaluation shall be done to insure that:

- the engineering is reasonably complete;

- all significant design problems (e.g., vulnerability, availability, human factors, logistic supportability) have been identified, and that

- there are solutions to the problems.

3. Operational Test and Evaluation II. This phase of operational test and evaluation should provide a valid estimate of operational effectiveness and suitability. OT II would include tests on operating instructions, documentation, publication, and handbooks.

4. Update DCP. After the tests and evaluation, the DCP is again updated to recommend the system for production and deployment.

5. DSARC III/(S)SARC II. Directive 5000.2 (Enclosure 2, IV. C) states that the DSARC III/(S)SARC III reviews are to address the following issues for the Milestone 3 decision:

- The mission element task to be accomplished is reaffirmed and the threat updated.
- The development has progressed satisfactorily, and the initial operational test and evaluation results support a decision to proceed with production and deployment.
- The acquisition strategy has been updated and is being executed.
- Business planning supports the acquisition strategy and provides flexibility for production rates and quantities when options are used.
- Schedule and cost estimates are realistic and acceptable including support and operating costs. (Reference DOD Directive 5000.4)
- Design-to-cost and life cycle cost requirements are realistic and effective in achieving cost objectives.

- The system is cost-effective and affordable and remains the best alternative.
- Tradeoffs have been made to balance cost, schedule, and performance effectively.
- Program and fiscal year thresholds are reaffirmed.
- Production quantity requirements are valid.
- Issues concerning production, producibility, quality assurance, and facilities are identified and managed satisfactorily.
- The program management structure and plan are sound and adequately supported.
- Major problems are identified and satisfactorily resolved.
- NATO standardization and interoperability requirements have been satisfied.
- Requisites for future production decisions have been defined, and competition has been considered through second source, etc.
- Planning for deployment is adequate, including manpower and training logistics readiness and operational considerations including integration with existing operational systems.
- Assessment of support subsystems to meet needs of initial operational units and planning to meet any deficiencies are carried out.
- Production readiness review is completed; contractor has adequate capability to manufacture the system.

6. Milestone 3. At Milestone 3, the Secretary of Defense can cancel, approve, or have further studies conducted on the system.

Production and Deployment Phase

The events in the Production and Deployment Phase are shown in Exhibit 6. If the system is approved for the Production and Deployment Phase, then a decision has to be made for either limited or full production. Generally, if more testing is required, the decision will be for limited production; if there are no or few outstanding issues to be resolved, the decision will be for full production.

1. Developmental Test and Evaluation III. If DT III is required, adequate testing shall be done to resolve any outstanding issues or for:

- product improvements;
- operational modification to meet identified threat change; or
- changes to reduce system life cycle costs.

2. Operational Test and Evaluation III. OT will continue as necessary to refine operational effectiveness estimates, to evaluate changes, and to re-evaluate the system in new environments or against new threats.

Deployment Preparation

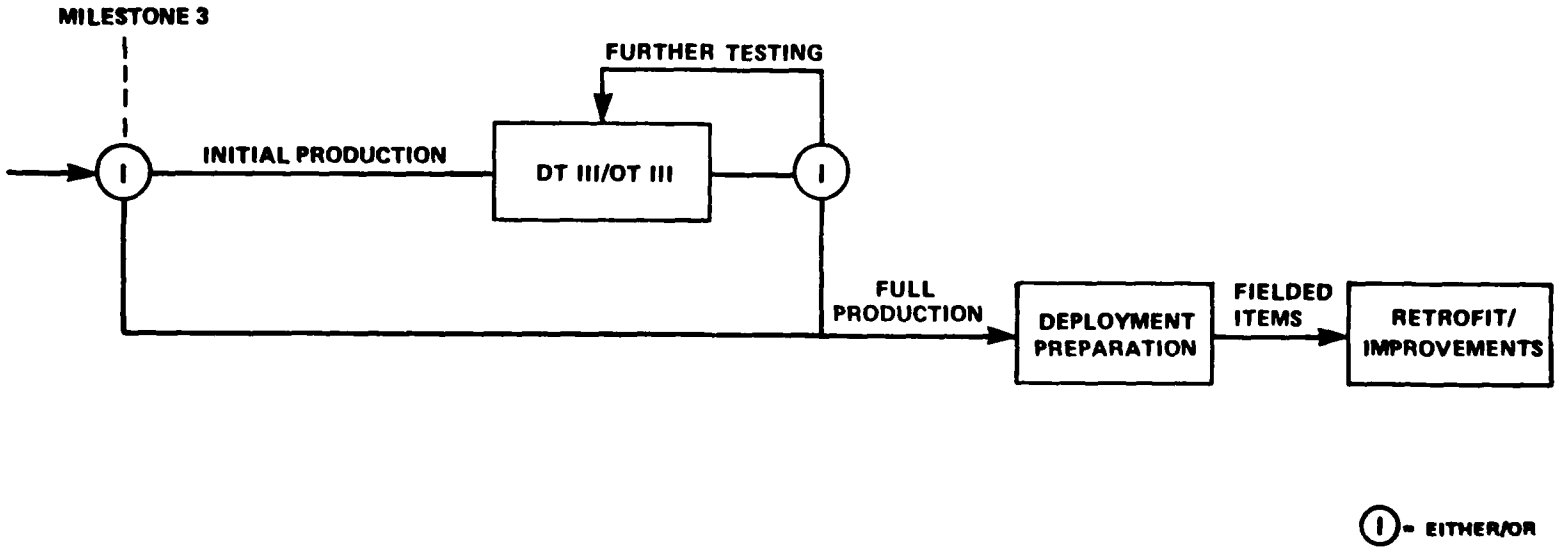
Production phasing, production management, production management transfer, and full-scale logistics support implementation are made firm for deployment.

Retrofit/Improvements

After the items are fielded, suggestions and/or complaints can result in product changes.

Exhibit 6

Events During the Production and Deployment Phase



Human Factors R&D: DOD Requirements

Evidence of the growing awareness of the need of human factors R&D in the system acquisition cycle can be seen in the promulgation of governmental and service-level human factors requirements and regulations. The purpose of this section is to review and integrate the human factors requirements from governmental-level documents that pertain to all phases of the system acquisition cycle.

Directives 5000.1, 5000.2, and 5000.3 give the requirements for any major governmental acquisition. In the sections below, relevant human factors requirements have been excerpted from the directives and discussed in the chronological phases of system development. In addition, excerpts from MIL-STD-1472B and MIL-H-46855B are used to complement the human factors R&D governmental requirements for system development.

Mission Analysis Phase

Each DOD Component Head is responsible for maintaining on-going analyses to identify new threats or technological breakthroughs. When either are identified, the DOD Component Head prepares a Mission Element Needs Statement (MENS) that describes the mission, how the mission is to be supported, and provides justification of a new major system acquisition. In addition to providing the justification, the MENS is to provide the planning for a system program office and to detail a program plan to explore alternative systems to meet the threat or to maximize the benefit of a technological breakthrough.

The MENS must address several important human factors R&D issues. Directive 5000.2 requires that the MENS:

- State the known constraints to apply to any acceptable solution including operational and logistics considerations, requirements for NATO standardization or interoperability, limits on the resource investment to be made, timing, etc. These constraints will constitute the boundary conditions for the exploration of alternative solutions. (5000.2, IV.C.1.e)

Man is going to play a role in the new projected mission either in carrying out the mission or supporting the mission or both. HF R&D will be needed to determine the most effective role of man in the system and to determine if the proposed mission requires unrealistic human performance standards or unrealistic operational and logistical requirements. Determining realistic human performance constraints will impose additional boundary conditions and eliminate consideration of and the building of systems in which man cannot properly perform to the extent intended. With proper HF R&D, the correction of such design errors can occur at the program beginning and not downstream where changes are more difficult to implement and more costly to make. In the worst case, the design errors are not detected until after the system is fielded. In such a case, a seemingly superior system always will operate in a degraded mode as long as the system does not account for man's capabilities and limitations. If man's capabilities are not maximized, the system will be suboptimal. If man's limitations are not taken into account, man will be the bottleneck. The removal of the bottleneck generally means costly system redesign.

Another responsibility of the DOD Component Head is to maintain a research program to achieve technological breakthroughs and develop data bases for use in future systems.

- The ability to achieve required system capabilities within acceptable risk and cost is dependent upon a strong and usable technology base. The Head of each

> DOD component is responsible for assuring continued technology advancement both in product and in manufacturing technology to support future system developments. This technology base shall be maintained by the DOD Components . . . . (5000.1, IV.G)

The directives clearly state the need for early test and evaluation, for early determination of probable operational system effectiveness, and for determining what resource constraints may exist. Of interest to HF R&D are tests and evaluation of the effectiveness of the alternative roles of man, analyzing similar systems for their operational effectiveness, and developing systems that maximize man's capabilities and minimize his limitations.

- Test and evaluation shall be commenced as early as possible and conducted throughout the system acquisition process as necessary to assess and reduce the acquisition risks and to evaluate the operational effectiveness and operational suitability of the system being developed. Meaningful critical issues, test criteria, and measures of effectiveness related to the satisfaction of mission need shall be established prior to the commencement of tests. (5000.3, C.1.a)

- Before the initiation of development of a new system, test and evaluation using existing systems, or modifications thereto, should be conducted when appropriate, to help define the military need and operational concept for the proposed new system and to estimate its operational effectiveness and operational suitability. (5000.3, C.1.d)

- Dependence on subjective judgment concerning system performance shall be kept to a minimum during testing. To the extent permitted by resource constraints and the need for realistic test environments, appropriate test instrumentation will be used to provide reliable and adequate data for systems evaluation. (5000.3, C.1.e)

MIL-H-46855B states that human factors engineers are to be involved in determining the role of man in the system and in function identification.

- Estimates of Potential Operator/Maintainer Processing Capabilities - Plausible human roles (e.g., operator, maintainer, programmer, decision maker, communicator, monitor) in the system shall be identified. Estimates of processing capability in terms of load, accuracy, rate and time delay shall be prepared for each potential operator/maintainer information processing function. These estimates shall be used initially in determining allocation of functions and shall later be refined at appropriate times for use in definition of operator/maintainer information requirements and control, display and communication requirements. In addition, estimates shall be made of the effects on these capabilities likely to result from implementation or nonimplementation of human engineering design recommendations. (3.2.1.1.2)

- Starting with a mission analysis developed from a baseline scenario, the functions that must be performed by the system in achieving its mission objectives shall be identified and described. (3.1.1.a)

Concept Development Phase

The need for integration of HF R&D in all aspects of system development is clearly recognized in DOD Directive 5000.1. In addition, the Directive recognizes that the system design will influence the number of persons and the skill level required to operate and maintain the system.

- The number and skill levels of personnel required and human engineering factors shall be included as constraints in system design. The integration of the human element and system shall start with initial concept studies and refined as the system program progresses to form the basis for personnel selection and training, training devices, simulators, and planning related to human factors (5000.1, IV.W)

- Logistic support planning including reliability and maintainability shall be consistent with the key program decisions and phases of activity. Alternative maintenance concepts shall be considered during the exploration of alternatives to identify the impact on system design and resources (5000.1, IV.V)

- Test and evaluation shall commence as early as possible. (5000.1, IV.V)

A major activity for HF R&D in this phase is function allocation. MIL-H-46855B states that this activity will be done:

- Defining and Allocating System Functions - The functions that must be performed by the system in achieving its objective(s) within specified mission environments shall be analyzed. Human engineering principles and criteria shall be applied to specify personnel-equipment/software performance requirements for system operation, maintenance and control functions and to allocate system functions to (1) automatic operation/maintenance, (2) manual operation/ maintenance, or (3) some combination thereof. Function allocation is an iterative process achieving the level of detail appropriate for the level of system definition. (3.2.1.1)

It is the Program Manager's responsibility to develop a good plan for the exploration of alternative concepts. The Program Manager will need man-machine and man-machine-environment HF inputs to determine which man-machine combinations are to be effective in the given mission environment and to avoid marginally effective alternatives.

- Business planning should emphasize early competitive exploration of alternatives to avoid premature commitment to solutions that may prove costly and marginally effective. The solicitation for proposed solutions shall be in terms of mission needs and not explicit system characteristics and shall provide complete information including the mission task and the operating environment and threat to enable all sources to respond fully to the need. (5000.2, IV.E.1.e)

- The Program Manager shall systematically and progressively explore and develop alternative system concepts to satisfy the approved need. (5000.1, IV.D.1.b)

Through the HF and other inputs, the Program Manager makes the performance, cost, and schedule program trade-off decisions for the current system. The Program Manager also must make provisions to incorporate the experience gained on the present system to become part of a data base for future system decisions.

- Every effort shall be made to prevent the expenditure of resources to achieve unnecessary performance and schedule requirements. Meaningful relationships shall be established between system capability, cost, and schedule. The Program Manager shall take positiv action to continually assess program risk areas and to make or propose trade-offs in performance, cost, and schedule to achieve the best balance. (5000.2, IV.F.6)

- A realistic work breakdown structure shall be developed for each program as a framework for planning and assignment of responsibilities, control and reporting progress, and use as a data base in making future cost estimates of new defense systems. (5000.2, IV.F.11)

Directive 5000.3 has provisions for developmental or operational testing in the Concept Development Phase if the PM feels it is needed to choose the best alternative. HF inputs are needed for any operational test.

- During the Concept Development Phase following Milestone 0, adequate DT&E shall be accomplished when appropriate to assist in selecting preferred alternative system concepts. (5000.3, C.2.b)

- During the Concept Development Phase following Milestone 0, OT&E will be conducted when appropriate to assess the operational impact of the candidate technical approaches and to assist in selecting preferred alternative system concepts. (5000.3, C.3.a(1))

Directive 5000.3, paragraph 3 calls for an independent test planner/evaluator. Generally, this independent evaluation comes during DT/OT II, but could, under certain circumstances, begin as early as DT/OT I. The responsibilities of the independent test and evaluation agency are:

- Participate in initial program planning of DT&E to ascertain what portion of DT&E will contribute to the accomplishment of OT&E objectives.

- Monitor and review the results of DT&E as necessary to obtain information applicable to OT&E objectives and to assess the readiness of the system for operational testing.

- Insure that the various phases of OT&E are scheduled to allow adequate time for a thorough review, analysis, and reporting of test results.

- Bring directly to the attention of its Military Service Chief and Service Secretary, or Defense Agency Director, those program issues which impact adversely on the accomplishment of adequate OT&E.

- Provide to its Service Systems Acquisition Review Council an assessment as to the results and adequacy of operational testing accomplished to date and the adequacy of operational testing planned for the future to support the Council's recommendations.

- Provide each DOD Component within its immediate headquarters staff a strong, full-time, focal point organization to assist the independent OT&E field agency to keep its Military Service Chief and Service Secretary, or Defense Agency Director, fully informed as to OT&E needs and accomplishments.

- Coordinate test planning for DT&E and OT&E at the test design stages so that each test cycle requires minimum resources and yields the data necessary to satisfy the common needs of the materiel developing agency and the OT&E agency. The purpose of the coordination is to preclude unnecessary duplication. In general, OT&E will be conducted separately from DT&E; however, they may be combined where clearly identified and significant cost/time benefits would result, or where separate testing would result in delay involving unacceptable military risk or an unacceptable increase in the acquisition cost of the system. When combined testing is conducted, the necessary test conditions and test data required by both the developing agency and the OT&E agency must be realized. Therefore, the developing agency, through coordination with the OT&E agency, must insure that the combined test is so planned and executed as to provide the necessary operational test information and that the OT&E agency is afforded the opportunity to participate actively in the test design and execution. The OT&E agency shall provide a separate evaluation of the resultant operational test information. As a normal practice the operational tests supporting a production decision will be conducted independently by the OT&E agency.

- Structure acquisition programs so that operational testing is commenced as early as possible in the development cycle. As a minimum, an initial phase of operational test and evaluation (IOT&E) will be accomplished prior to the Production and Deployment Decision Milestone 3. Such IOT&E shall be adequate to provide a valid estimate of expected system operational effectiveness and operational suitability. Preproduction prototypes or full-scale development items will be employed for IOT&E if they are reasonably representative of the expected production items and will allow a valid estimate to be made of expected system operational effectiveness and operational suitability; otherwise, pilot production items will be employed for IOT&E.

Decision Coordinating Paper

After testing and analyzing the alternative concepts, the Decision Coordinating Paper (DCP) should identify the critical issues and areas of risk to be addressed by test and evaluation (Directive 5000.3, C.10.a). HF R&D is needed to address the human, human-machine, and human-machine-mission issues to resolve any debilitating system aspects. HF R&D is also needed to provide human, human-machine, and human-machine-mission measures of effectiveness related to satisfaction of mission need (Directive 5000.3, C.10.a). In summary, the Directives call for the following issues, all of which need HF R&D analysis:

- Description of the alternative programs, including anticipated performance information. (5000.2, Enclosure 2, II.C)
- Areas of program uncertainty (excluding technical risks) and the probable impact. (5000.2, Enclosure 2, III.G)
- Program issues, including their assessment (5000.2, Enclosure 2, II.N)
- DCPs prepared for Milestone 1 shall contain program management constraints for selected program factors for each alternative as the basis for continuing the competitive demonstration effort for the particular alternative. (5000.2, Enclosure 2, II.K)

- Each DCP prepared for Milestones 1 and 2 shall contain a Technology Assessment Annex (TAA) that will identify any area of technological risk remaining in the program and describe plans for addressing these risks. (5000.1, Enclosure 2, III.H)

- DCPs prepared for Milestones 2 and 3 shall contain firm program schedules, cost, and performance information. Program thresholds shall be established for selected performance, cost, and schedule factors representing acceptable, projected variances at program completion and fiscal year thresholds for the same cost and schedule factors to represent acceptable variances at the end of each fiscal year. (5000.1, Enclosure 2, III.L)

- Test and evaluation planning and status. (5000.2, Enclosure 2, II.M)

At the next decision point, Milestone 1, the issues to be addressed by (S)SARC, DSARC, and the Secretary of Defense are contained in Directive 5000.2, Enclosure 2. The following excerpts are HF-related.

- The alternative system design concepts adequately reflect the technology base and provide an acceptable competitive environment. (IV.A.3)

- The alternatives recommended for competitive system demonstration meet the mission element needs. (IV.A.5)

- The established program constraints remain valid. (IV.A.6)

- The projected resource investment for the selected alternatives and other characteristics related to the alternatives are consistent with the stated constraints. (IV.A.7)

- Operational and logistical considerations are adequate. (IV.A.8)

- NATO standardization and interoperability requirements have been adequately considered. (IV.A.14)

- Risk and uncertainty areas are identified and adequately treated in the planning. (IV.A.15)

- Environmental considerations are adequate (IV.A.16)
- Planning and schedules for preparation of the Test and Evaluation Master Plan (TEMP) are adequate. (IV.A.17)

Demonstration and Validation Phase

Competitive systems demonstrations are conducted to validate the design concepts and to provide a basis for selection of a system for full-scale development and subsequent production. Directive 5000.2 (IV.F.8) states that the demonstrations should be conducted with full-scale prototypes in realistic operating environments when feasible and practical. When demonstrations at the system level are determined not to be feasible and practical, competitive prototypes demonstrations of critical subsystems shall be considered in the same manner as systems. Human factors test and evaluation are needed in this system development phase to assure that the proposed man-machine-mission interfaces are feasible and produce good performance in a realistic operating environment. The test and evaluations provide inputs for the next phase, as system design should not yet be firm. Specifically, Directive 5000.1 (IV.Q) states that:

- Performance, cost, and schedule estimates shall not be formalized or considered firm prior to the Milestone 2 decision since systems are not adequately defined and the value for these system parameters remain uncertain during the early phases of the system acquisition process.

The Test and Evaluation Master Plan (TEMP) should specify how the competitive systems are to be evaluated. All test and evaluation aspects, including human factors, should be contained in the TEMP. The DOD Component is responsible for developing this plan.

- The DOD Component shall prepare, as early as possible in the acquisition process, an initial version of the overall test and evaluation plan. This broad plan should identify and integrate objectives, responsibilities, resources,

and schedules for all T&E to be accomplished prior to the subsequent key decision points. The TEMP will be kept current by the DOD Component. (5000.3, C.8)

Task analysis is a major activity in this phase. MIL-H-46855B states the purpose and need of these analyses:

- The analyses shall provide one of the bases for making design decisions; e.g., determining, to the extent practicable, before hardware fabrication, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel, and assuring that human performance requirements do not exceed human capabilities. These analyses shall also be used as basic information for developing preliminary manning levels; equipment procedures; skill, training and communication requirements; and as Logistic Support Analysis inputs, as applicable. Those gross tasks identified during human engineering analysis which are related to end items of equipment to be operated or maintained by personnel and which require critical (see 6.2.1) human performance, reflect possible unsafe practices or are subject to promising improvements in operating efficiency shall be further analyzed, with the approval of the procuring activity. (3.2.1.3.1)

- Each task is analyzed to determine the human performance parameters, the system/equipment/software capabilities, and the tactical/environmental conditions under which the tasks are conducted. Task parameters shall be quantified, where possible, and in a form permitting effectiveness studies of the crew-equipment/software interfaces in relation to the total system operation. The identification of human engineering high risk areas shall be initiated as part of the analysis. (3.1.1.a)

- Further analysis of critical tasks shall identify the: (1) information required by operator/maintainer, including cues for task initiation; (2) information available to operator/maintainer; (3) evaluation process; (4) decision reached after evaluation; (5) action taken; (6) body movements required by action taken, (7) work-space envelope required by action taken; (8) workspace available; (9) location and condition of the work environment; (10) frequency and tolerances of action; (11) time base; (12) feedback informing operator/maintainer of the adequacy of actions taken; (13) tools and equipment required; (14) number of personnel required; (15) job aids or references required; (16) communications

required, including type of communication; (17) special hazards involved; (18) operator interaction where more than one crew member is involved; (19) operational limits of personnel (performance); and (20) operational limits of machine and software. The analysis shall be performed for all affected missions and phases including degraded modes of operation. (3.2.1.3.2)

At the present time, the Triservice Human Factors Test and Evaluation sub-group of the Department of Defense Human Factors Engineering Technical Advisory Group (TAG) has begun development of a coordinated means for task analysis development. While it was unavailable for review in this technical report, it is understood that it will supersede the task analysis requirements as specified in MIL-H-46855.

MIL-STD-1472B

The purpose of MIL-STD-1472B is to establish human engineering design criteria for the design and development of military systems and facilities. The concerns of MIL-STD-1472B range from function allocation to safety, control-display relationships, visual displays, audio displays, controls, labeling, anthropometry, workplace design, environment, maintainability design, equipment for remote handling, and aerospace vehicle compartments design requirements. While 1472B may be useful in considering the ramifications of options in the Mission Analysis and Concept Development Phase, the primary use of 1472B is in insuring contractors' adherence to the human factors R&D requirements in the Demonstration and Validation Phase, Full-Scale Development Phase, Production Phase, and for improvements and retrofits after the Production and Deployment Phase.

Developmental testing is the proper time to test the man-machine interface. The purposes of developmental test and evaluation are to identify the preferred technical approach

(Directive 5000.3, C.2C) and to assist the engineering design and development process and verify attainment of technical performance specifications and objectives (Directive 5000.3, C.2). Developmental test and evaluation includes testing of components, subsystems, hardware/software integration, and prototypes (Directive 5000.3, C.2.a). To be sure that the new system will not negatively interact with existing or planned equipment and systems, it is necessary to test the compatibility and interoperability of interfacing equipment.

Operational testing should occur in a realistic environment and is the time to test the human-machine-mission interface. Directive 5000.2 (C.3.a(2)) states that:

- During the Competitive Systems Demonstration Phase, OT&E will be conducted, as necessary, in as realistic an environment as possible in order to examine the operational aspects of selected technical approaches, and to provide information relative to projected operational effectiveness and suitability of the candidate systems.

Directive 5000.3(c.3) is more complete about the issues in operational test and evaluation.

- OT&E is that test and evaluation conducted to estimate a system's operational effectiveness (including survivability/vulnerability) and operational suitability (including availability, compatibility, transportability, interoperability, reliability, maintainability, safety, human factors, logistic supportability, and training requirements), as well as the need for any modifications. In addition, OT&E provides information on organization, personnel requirements, doctrine, and tactics. It may also provide data to support or verify material in operating instructions, software documentation, publications, and handbooks. OT&E will be accomplished by operational and support personnel of the type and qualifications of those expected to use and maintain the system when deployed, and will be conducted in as realistic an operating environment as possible, including enemy countermeasures. It will address operational performance of component systems, including new or improved

components and their interaction with related existing systems. Costs directly related to operational testing in a program shall be planned, programmed, and budgeted by the cognizant DOD component.

Following developmental and operational test and evaluation, the DCP is updated to give:

- The results of T&E accomplished to date; and updated statement of critical issues, test objectives, and areas of risk needing further assessment, a summary of performance criteria goals and thresholds, and an overview of test plans, milestones, and program interrelationships. The cognizant Component shall make available supporting details of test plans and test results as requested by the DDTE or ASD (PA&E). (5000.3, C.10.b)

Excerpts from Directive 5000.2 give the human factors Milestone 2 issues to be addressed.

- System tradeoffs have produced the most effective balance in cost, performance, and schedule including operational and logistical considerations. (IV.B.5)

- Uncertainties and risks have been identified and are acceptable; planning to resolve the remaining uncertainties and risks is adequate. Realistic fall-back actions and alternatives have been established. (IV.B.6)

- Cost, performance, and schedule estimates and related thresholds have been thoroughly reviewed and are well defined and consistent with risks involved. These values shall be established as firm estimates. (IV.B.10)

- Demonstration and validation testing and evaluations have been completed and results support the recommendations. (IV.B.13)

- Requirements have been established for long-lead procurement items and initial limited production to support operational test and evaluation needs, for the verification of production engineering and design maturity, and to establish the production base. (IV.B.16)

- The system selected meets the mission element needs, is cost-effective, and is acceptable within stated constraints. (IV.B.2)

- NATO standardization and interoperabolity requirements are satisfied. (IV.B.3)

- The Test and Evaluation Master Plan (TEMP) identifies and integrates the testing and evaluation to be accomplished prior to the Milestone 2 and 3 program decision points. (IV.B.17)

- Requisites for the Milestone 3 production and deployment decision including operational and logistical support have been established. (IV.B.18)

Full-Scale Development Phase

By the end of this phase, the hardware configurations and the subsystem structures become firm unless design errors are found.

- Subsystems selected for use in a system acquisition program shall not be fully developed until the system program has been approved for full-scale engineering development. (5000.2, IV.F.3)

Because the hardware configuration is becoming firm, it is important that the contractors have human factors personnel to analyze and propose the proper man-machine interface. Likewise, it is important that the contractor's proposals have design requirements that fulfill the human factors specifications, e.g., MIL-STD-1472B.

The degree of use of human factors data, methodology, and expertise in the developing system will be only as good as that required of the contractors by DOD.

- Contractors shall be required to submit firm proposals for full-scale engineering development and initial production upon completion of the competitive systems demonstration and shall be provided with the factors, criteria, and conditions to be used by the DOD in the

evaluation and selection of a system for full-scale engineering development. Specifications and standards and a contract data list shall be identified and tailored by the contractors for application to the system proposal for full-scale development on the basis of the competitive systems demonstration results. (5000.2, IV.F.8)

Proper human factors inputs should make the system more cost effective. The results of human factors analyses should be used in calculating operating maintenance life cycle costs. Decisions resulting from human factors analyses can affect needed skill levels to operate the system, amount of training, type of documentation, operating and maintenance error rates, and the maintenance philosophy.

- Costs of acquisition and ownership shall be established as separate cost elements and translated into firm design-to-cost and life cycle cost requirements for the system selected for full-scale engineering development. System program actions shall be evaluated against these requirements with the same rigor as the evaluation of technical requirements. (5000.2, IV.F.7)

Logistical planning also becomes firm in this phase:

- Detailed logistics planning shall be initiated with full-scale engineering development and firm requirements established early in the phase. The adequacy of logistics plans, and resources to meet readiness objectives, will be reviewed as part of the Milestone 3 production decision. (5000.1, IV.V)

The human factors issues should be resolved during this phase:

- During the Full-Scale Engineering Development Phase prior to the Production and Deployment Decision (Milestone 3), the DT&E accomplished shall be adequate to insure: that engineering is reasonably complete; that all significant design problems (including survivability/vulnerability, availability, producibility, compatibility, transportability, interoperability, reliability, maintainability, safety, human factors, electromagnetic compatibility, and logistic supportability) have been identified and that solutions to these problems are in hand. (5000.3, C.2.d)

Human factors test and evaluation plays a major role in full-scale development operational testing.

- An estimate of military utility and of operational effectiveness and operational suitability, including logistics support requirements, shall be made prior to large-scale production commitments. The most realistic test environment possible and an acceptable representation of the future operational system will be used in the testing. (5000.1, IV.U)

While the directives call for operational testing in the prior phase, the first complete and major operational test is intended to occur during the Full-Scale Development Phase.

- OT&E will normally be conducted in phases, each keyed to an appropriate decision point; OT&E conducted prior to the Milestone 3 decision is designated Initial Operational Test and Evaluation (IOT&E). (5000.3, C.3.a)

- During the Full-Scale Engineering Development Phase, following the Milestone 2 decision, adequate OT&E will be accomplished to provide a valid estimate of operational effectiveness and suitability. (5000.3, C.3.a(3))

Those human factors issues to be addressed at Milestone 3 have been taken from Directive 5000.2.

- The development has progressed satisfactorily and the initial operational test and evaluation results support a decision to proceed with production and deployment. (IV.C.2)

- Schedule and cost estimates are realistic and acceptable including support and operating costs. (IV.C.5)

- Tradeoffs have been made to balance cost, schedule, and performance effectively. (IV.C.8)

- Major problems are identified and satisfactorily resolved. (IV.C.13)

- NATO standardization and interoperability requirements have been satisfied. (IV.C.14)

- Planning for deployment is adequate, including manpower and training logistics readiness; and operational considerations, including integration with existing operational systems. (IV.C.16)

- Assessment of support subsystems to meet needs of initial operational units and planning to meet any deficiencies. (IV.C.17)

Production and Deployment Phase

Once a system goes into production, there are opportunities for inputs and changes in the system configuration on an as-needed basis.

- Following a Milestone 3 decision, the DOD Component Head shall make quarterly reports to the Secretary of Defense on key program issues. The DOD Component shall keep the Defense Acquisition Executive and the OSD staff informed on key program actions as the program progresses. (5000.1, IV.D.4.b)

- In case of DCP revisions and DSARC or (S)SARC reviews subsequent to the Production and Deployment Decision an updated assessment of test results, plans, objectives, and schedules for additional test and evaluation will be provided. (5000.3, C.10.d)

While developmental and operational testing occur on an as-needed basis, production acceptance test and evaluation (PAT&E) is required during this phase.

- During the Production and Deployment Phase following the Milestone 3 decision, DT&E will be an integral part of the development, acceptance, and introduction of:

  (1) Product improvements into the produced system.

  (2) Operational characteristic modifications to meet identified threat changes.

  (3) Changes to reduce system life cycle costs. (5000.3, C.2.e)

- Subsequent to the Milestone 3 decision, OT&E will be continued as necessary to refine estimates of operational effectiveness, to evaluate changes, and to re-evaluate the system to ascertain whether it continues to meet operational needs and retains its effectiveness in a new environment or against the current or projected new threat. (5000.3, C.3.a(4))

- PAT&E is test and evaluation of production items to demonstrate that items procured fulfill the requirements and specifications of the procuring contract or agreements. It is the responsibility of each DOD Component to accomplish the necessary PAT&E throughout the Production and Development Phase of the acquisition process. (5000.3, C.7)

In summary, the DOD Directives, MIL-H-46855B, and MIL-STD-1472B state the need for human factors R&D in all system acquisition phases. These human factors R&D analyses are conducted to insure that the most operationally and cost-effective system is developed within the constraints of the program.

Human Factors R&D: Service Requirements

Service regulations and instructions that document human factors activities, albeit of a general nature, provide the framework for activities throughout the military system acquisition process. To the extent possible, requirements for human factors will be related to the overall system acquisition cycle as well as to specific phases within it. The intent is to show the degree to which the services are concerned with the integration of human factors R&D into the process by which new military systems are acquired and developed. The three pertinent documents are:

1. Department of the Air Force, AF Regulation 800-15. *Human Factors Engineering and Management.*
2. Department of the Army, Army Regulation 602-1. *Human Factors Engineering Program.*
3. Department of the Navy, NAVMATINST 3900.9. *Human Factors.*

Generally, topics covered in these documents have included:

- definitions of human factors and/or human factors engineering,
- broadly based descriptions of activities and functions of human factors,
- designated responsibilities for human factors,
- extent of involvement of human factors with system life cycles, and
- coordination of requirements with documentation such as military specifications and standards.

The intent has been to provide generic data requirements and not to restrain human factors developments and innovations. In fact, innovation in human factors methodology application is encouraged. The following quote from Army Regulation 602-1, illustrates this point:

> Human Engineering standards which embody well-tested human factors principles or prescribe design standardization to minimize cross-training or relearning problems are appropriate as guidelines . . . . *These standards should not preclude design approaches which can lead to improved performance of the personnel-materiel system.*

On the other hand, informal requirements (e.g., handbooks, guidebooks, and manuals) for human factors espoused by the different services have been more disposed to discuss methodology applications. Whatever human factor elements are included and whatever the depth with which these have been discussed, the overall emphasis seems to be the placement of human factors in system development as a total systems view.

Overall Military System Acquisition Human Factors R&D Requirements

Since the service documents are more directly oriented to the definition and activity requirements for human factors, and less concerned with specific functions as they relate to system development, most statements involving human factors R&D in development of systems cover the overall process. This results in a greater level of general detail. The intent is to provide few constraints upon use of human factors methods by allowing for greater flexibility.

Greatest detail with regard to the overall process is provided in the Army regulation. As well as detailing the events themselves, this document provides information about when human factors requirements should be invoked.

In addition to detailing the kinds of events relevant to the overall process of human factors R&D in system development, the Army regulation provides information about when human factors requirements should be invoked.

> During all phases of the life cycle for materiel systems, accepted principles of HFE will be used to integrate material development with personnel resources and will have an associate priority with all other systems characteristics. Personnel implications will be considered throughout all development activities. Human factors studies or behavioral research will be initiated when gaps in HFE data base exist and where novel human factors problems are identified in Army development programs. During all phases of systems development, the interactive effect of system concept, hardware design, software design, personnel performance requirements, and training requirements must be recognized.

The Department of the Navy instruction provides requirements which are of primary concern to the Navy in systems development. In fact, the Navy considers it necessary for the "human element" to proceed through developmental steps similar to that of hardware.

> Human factors engineering is concerned with the analysis and design of systems to achieve operability and supportability with the human operator/maintainer in the system. The effort begins with the performance requirements analysis and includes information flow analysis, function allocation, maintenance/maintainability analysis, equipment design, crew station design, test, and evaluation.
>
> *The Naval Materiel Command human factors policy requires that the human element of Navy systems shall undergo the same development, test, and*

evaluation steps as equipment elements of the same system. This requires integration of appropriate human factors information into design and its use in all major management and/or technical decisions and documents.

The Department of the Air Force regulation attempts to legitimize human factors within the engineering context by defining it as having a shared responsibility for system development through the system engineering approach. In addition, it recognizes the individual nature of each system and the manner by which human factors R&D must adapt to this feature.

> HFE is a part of the mainstream engineering effort throughout the system life cycle. *It is that component of systems engineering which seeks to optimize the system by integrating the human performance necessary to operate, maintain, support, and control the system in its intended operational environment.*
>
> The consideration of HFE requirements must begin with the inception of the system or equipment life cycle. The scope of this effort depends on the nature and the type of system or equipment program, and must be tailored to meet specific program objectives.
>
> *The policy stated in this regulation will be adapted to meet the unique requirements of each system or project, considering the specific phase of the system life cycle at hand, the scope of the system or project in work, and the special management needs of the total program.* The responsibility for HFE begins with the inception of the system or project and continues throughout the life cycle of each system or project.

Service Requirements for Human Factors R&D in Mission Analysis

Less often considered than the rest of the phases, mission analysis requirements are less clearly defined by the service documents. The Army regulation approaches the topic by including the elements deemed pertinent to description of a system's mission.

> It is important that decisions regarding mission, doctrine, basis of issue, unit organization and manning, personnel selection and training, and technical or training publications all be made from a coordinated data base including human factors engineering.

On the other hand, the Air Force refers to a concept often applied to mission analyses but does not refer to the phase at all.

> Man's role in the system is defined in order to optimize his performance in relation to that specific system.

Service Requirements for Human Factors in Concept Development

The services recognize the importance of critical human factors events which must be prevalent in the Concept Development Phase. Numerous varieties of studies are referred to which are of direct relevance to events that follow in later phases.

The Army regulation delineates specific portions of human factors R&D which must be initiated during this phase. In addition, it provides the logic for developing concept development data to be used as system development objectives for later stages.

> *HFE in the Conceptual Phase.* HFE will be initiated in the conceptual phase of the system's life cycle. During the conceptual phase, HFE, personnel plans, and training considerations will be integrated into the technical and management plans. HFE data developed during the conceptual phase will be considered during this phase in determining projected personnel requirements and in planning development of personnel-support programs and training programs. In the case of materiel with a very strong human interface, it is critically important to develop HFE data in the conceptual phase (RDTE category 6.2 and 6.3a) sufficient to provide a basis for thorough design and evaluation during Systems Oriented Advanced Development (RDTE Category 6.3b).

The Navy instruction states point-blank the requirement for human factors in concept development, since it is such a brief document.

> As a minimum this will involve human factors inputs to concept formulation.

The Department of the Air Force points out a requirement for human factors R&D in concept development. Rather than stopping there, the document lists the considerations that human factors studies must help address. In addition, they reinforce the life cycle nature of concept development activities, and, by implication, how human factors R&D products must be continually refined throughout the system development process.

> HFE must be an integral part of R&D conceptual study efforts . . . .
>
> Adequate man-machine analyses and trade-off studies are accomplished beginning with the conceptual phase and as appropriate throughout the system life cycle. These studies must consider life cycle costs, system performance requirements and complexity, and the capability of available personnel to perform the intended function.

Service Requirements for Human Factors R&D in the Demonstration and Validation Phase

System demonstration and validation is the phase whereby the services require the first detailed human factors analysis. The documentation links directly the design/development of the system prototype and the availability of human factors data.

The Army regulation points out that the Demonstration and Validation Phase offers a good opportunity for human factors contributions to design, since the system is in prototype development and the design has not been firmly set. In addition,

the document stresses the development of human factors items (e.g., training and training device plans, etc.) concomitant with other research in this phase.

> *HFE in the Validation Phase.* Systems Oriented Advanced Development (RDT&E Category 6.3b) is the preferred state of development for the completion of detailed HFE. *At this stage, prototypes representing the first concrete expression of the concept are available for test and evaluation, yet the design has not been frozen. As a result, sufficient information concerning the proposed design is available to support a detailed HFE analysis while this design is still sufficiently flexible to accommodate any change resulting from the recommendations of this analysis.* The requirement to initiate an HFE analysis as a part of 6.3b will be documented in the Letter of Agreement (LOA). It will include the designation of the agency with recognized HFE expertise responsible for conducting and reviewing the HFE analysis. Results of the analysis will include:
>
> (1) Tentative identification, allocation, and sequencing of operator and maintenance tasks to develop a concept of the training requirements for the soldier and the soldier's role in operating, using, or maintaining the materiel.
>
> (2) Identification of human factors research required to support the training requirement and the operational concept.
>
> (3) Identification of HFE guidelines, standards, processes, or criteria and other documentation necessary to insure that operational performance objectives for the personnel-materiel syst . can be achieved by personnel available in the organization employing the system.
>
> (4) Identification of training devices and aids, and special training requirements.

The Department of the Navy instruction is somewhat dated, and as a result, terminology does not always match current use. A term formerly associated with the Demonstration and Validation Phase is contract definition. Once again they simply state a requirement for this activity.

> As a minimum this will involve human factors inputs to . . . contract definition . . . .

Similarly, the Department of the Air Force regulation calls for activities during the Demonstration and Validation Phase.

> HFE must be an integral part of . . . exploratory (and) advanced . . . development.

Service Requirements for Human Factors R&D in the Full-Scale Development Phase

The intent of human factors activities as delineated by service requirements in the Full-Scale Development Phase is to define to the finest degree necessary the analyses required to support detail design of the system. This phase brings together much of the information prepared initially in earlier phases of system development.

The Army regulation defines specific requirements for information to support system development in this phase. Concern for performance of the human in the system is manifested by requirements for specific data (e.g., human performance reliability). Human factors data amenable to direct usage as design recommendations are also stressed.

> *HFE in Full Scale Development Phase.* Human factors research or engineering will be continued to insure the timely consideration of human factors in materiel development established during materiel concept investigations, advanced development, and the preparation of a Required Operational Capability (ROC), Letter of Requirement (LR), Training Device Requirement (TDR), or Training Device Letter Requirement (TDLR). Human factors research or engineering during engineering development will include more detailed task analysis and further refinement of operator and maintenance task sequences as the materiel design is finalized. These task sequences will be used to determine

> skill requirements and training implications and their impact upon organizational structure. Human engineering characteristics specified in the ROC, LR, TDR or TDLR should emphasize system effectiveness, human performance reliability, and personnel requirements. Human engineering standards which embody well-tested human factors principles or prescribe design standardization to minimize cross-training or relearning problems are appropriate as guidelines for ROCs, LRs, TDRs, and TDLRs. These standards should not preclude design approaches which can lead to improved performance of the personnel-materiel system.

The Navy instruction simply states some of the events taking place in the Full-Scale Development Phase.

> As a minimum this will involve human factors inputs to . . . engineering development, contractual statements of work, engineering change proposals, and test and evaluation plans.

Similarly, the Department of the Air Force regulation simply states a need for human factors activities in this phase.

> HFE must be an integral part of . . . engineering development projects . . . .

Service Requirements for Human Factors R&D Through Production and Post-Production Phases

In addition to the previously delineated requirements for human factors activities, the service documentation refers to requirements for activities throughout the balance of the system life cycle. These include production phases (low rate initial production, full production, and deployment), operation, and retrofit. As post-production deficiencies are identified, human factors activities must be implemented to resolve problems. Continuous cognizance of personnel and training requirements must be maintained in order to be aware of and resolve problems that

may arise as a result of changes or other factors. The intent is to convey responsibility for human factors R&D activities to all phases of system development and operation.

Informal Documents

Each service maintains informal documentation which involves substantial methodology applications, as stated in the introduction to this section. Informal documentation consists of the various handbooks, guidebooks, manuals, etc. that the services have prepared for use as guidance in system development cycles. Whereas the formal documents (regulations and instructions) contain detailed requirements and responsibilities for human factors, the informal documents do not. Instead, the informal documents provide guidance for methodologies (e.g., data acquisition and analysis), design constraints such as anthropometric data, and recommendations for what may be found in a good human factors program plan. The materials reviewed tend to be easily categorized under the following three topics:

1. Human Factors in System Development
2. System Design
3. Human Factors in Test and Evaluation.

Each topic will be briefly discussed in subsequent paragraphs. In addition, the materials applicable to each will be briefly reviewed.

Human Factors in System Development. A need for defining the role of human factors in military system development has been approached by the services in detail through informal documents. The following quote states the need most succinctly:

> Man is a system component and as such deserves systematic, specialized attention. System development program managers, because of a lack of familiarity with or interest in human engineering, have sometimes been responsible for

> relegating human engineering to a 'nonessential' status, only to find they are faced with costly redesign at a later date. (Coburn, 1973)

Coburn proceeds to develop a complete plan for human factors in the *Human Engineering Guide to Ship System Development*. With this approach, it is considered imperative that human factors be integrated into a program early in system development. In fact, this is a prime characteristic of all system development oriented human factors guides that were reviewed. The Naval Air Development Center prepared a complete management approach to human factors requirements in system development (Naval Air Development Center, 1974). This document encompasses the entire system acquisition cycle.

Although somewhat dated, a guide was prepared by the Army Human Engineering Laboratory that in its own words demonstrates a concern for human factors integration over the complete system life cycle. "The purpose of this guide is to explain and promulgate the procedures for integrating the . . . Human Factors Engineering Program . . . with the Life Cycle Management Model for Army Systems" (DA Pamphlet 11-25). (See: Manpower Resources Integration Guide for Army Materiel Development, Department of the Army, 1969.) Since this document related to the predecessor of the present LCSMM pamphlet, its utility may well be limited. Nonetheless, it describes a complete program in which human factors is fully a part of system development.*

The Air Force Systems Command has prepared a design handbook that contains expansions of requirements for human factors throughout the system development cycle (Air Force Systems Command, 1977). Taking a more generic stance, the *Human Engineering Guide to Equipment Design* (Van Cott & Kinkade, 1972) presents the

*It is understood that this guide is presently being revised and updated by the Human Engineering Laboratory.

reasoning behind complete integration of human factors throughout system development. All of the above articles present detailed methodologies for the application of human factors to the development of systems. Most at least attempt to place human factors activities within the structure of a system development cycle.

System Design Guidance. Developing a data base from which to draw human factors design contributions has long been a goal of the human factors specialist. MIL-STD-1472 is recognized as a primary source in this area. There are other documents available which have expanded upon this basic resource and are tailored with additional information for use upon specific system types. One representative document in this regard is MIL-HDBK-759 (Department of Defense, 1975). Developed for use by the Army, its purpose is to present human factors data which are sensitive to unique Army materiel requirements. The Air Force Systems Command has its own Design Handbook tailored for Air Force systems and equipment design in a manner similar to the Army's (Air Force Systems Command, 1977). Finally, the *Human Engineering Guide to Equipment Design* presents design oriented data and discussion.

Human Factors in Test and Evaluation. Test and evaluation of major systems has been a large concern in the services. Extensive documentation of human factors test and evaluation has been made. The Army Human Engineering Laboratory has been responsible for numerous test and evaluation guides. For the most part these have been superseded by the guides listed next. The most important guide along these lines contains a two volume set of human factors test procedures and guidance for test data evaluation (known as HEDGE--Human Engineering Data Guide for Evaluation) (Perkins et al., 1977). The test procedure volume includes specific test procedures and sample data collection forms. The HEDGE volume covers a range of topics, including:

test conditions, performance tasks, and detailed design criteria, as well as guidance concerning what to test. Another guide prepared by the Human Engineering Laboratory is based on a Data Item Description (DID) entitled, "Report(s) of Human Factors Engineering Test" (Berson & Crooks, 1976). Guidelines for conducting, analyzing, and reporting human factors tests were developed according to this DID. The guide also provides an application procedure. A special guide for evaluation prepared by the Human Engineering Laboratory was tailored to Army aviation requirements for human factors (Cassatt, 1965).

The Navy has developed a three volume manual for test and evaluation known as HFTEMAN (Human Factors Test and Evaluation Manual) (Department of the Navy, 1976). As a whole, HFTEMAN covers objectives, methods, procedures, conditions, analysis, and reporting techniques of test and evaluation. In addition, it includes topics such as test measurements, criteria, and standards for use in system testing. Finally, the *Human Engineering Guide to Equipment Design* includes a discussion entitled, "Human Engineering Test and Evaluation." This discussion extends from field testing through laboratory controlled experiments, describing inherent advantages and disadvantages of each.

Conclusions

The purpose of the preceding discussion of service requirements for human factors R&D in military system acquisition is to support the view that policy does, in fact, exist which requires human factors activities throughout the life cycle of a system. This starts with mission analysis and ends when the system becomes obsolete and is withdrawn from use.

Three points can be drawn to conclude this discussion:

1. The service documentation delineates specific requirements for human factors activities.
2. Requirements for human factors activities are provided for each phase of the military system acquisition process.
3. The trend in formal requirements is to define requirements and responsibilities for human factors without placing constraints upon the methodology, analysis, and data characteristics used in research. The informal documentation, on the other hand, covers primarily those topics not promulgated in the formal requirements such as methodological options.

References

Berson, B.L., & Crooks, W.H. Guide for obtaining and analyzing human performance data in a materiel development project. Technical Memorandum 29-76. Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, September 1976.

Cassatt, R.K. An evaluation guide for Army aviation human factors engineering requirements. HEL-Standard-S-5-65. Aviation Branch, Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, November 1965.

Coburn, R. Human engineering guide to ship system development (responsibilities, procedures, and methods for carrying out human engineering programs). NELC-TD-278. San Diego, CA: Naval Electronic Laboratory Center, October 1973.

Department of the Air Force. Human factors engineering and management. AF Regulation 800-15. Headquarters, U.S. Air Force, Washington, D.C., October 1974.

Department of the Air Force. Human factors engineering. AFSC Design Handbook 1-3. Headquarters, Air Force Systems Command, Andrews AFB, MD, January 1977.

Department of the Army. Human factors engineering program. AR 602-1. Headquarters, Department of the Army, Washington, D.C., June 1976.

Department of the Army. Manpower resources integration guide for Army materiel development. HEL Guide 1-69. Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory, January 1969.

Department of Defense. Major system acquisitions. DOD Directive 5000.1, January 18, 1977.

Department of Defense. Major system acquisition process. DOD Directive 5000.2, January 18, 1977.

Department of Defense. Test and evaluation. DOD Directive 5000.3, April 11, 1978.

Department of the Navy. Human factors. NAVMATINST 3900.9. Headquarters, Naval Material Command, September 1970.

Department of the Navy. Human factors test and evaluation manual (HFTEMAN). Volume 1. Data Guide. TP-76-11A. Point Mugu, CA: Pacific Missile Test Center, October 1976.

Department of the Navy. Human factors test and evaluation manual (HFTEMAN). Volume 2. Support Data. TP-76-11B. Point Mugu, CA: Pacific Missile Test Center, October 1976.

Department of the Navy. Human factors test and evaluation manual (HFTEMAN). Volume 3. Methods and procedures. TP-76-11C. Point Mugu, CA: Pacific Missile Test Center, October 1976.

Human engineering design criteria for military systems, equipment, and facilities. Military Specification MIL-STD-1472B, May 1978.

Human engineering requirements for military systems, equipment, and facilities. Military Specification MIL-H-468558, 1979.

Office of Federal Procurement Policy. Major system acquisitions: A discussion of the application of OMB Circular No. A-109, OFPP Pamphlet No. 1, August 1976.

MIL-HDBK-759. Military standardization handbook. Human factors engineering design for Army materiel. Department of Defense, Washington, D.C., March 1975.

Naval Air Development Center. Human engineering requirements manual for evolving systems (HERMES). Volume 1. Prepared under Contract N62269-71-C-0348 for Naval Air Systems Command, Washington, D.C., June 1974.

Naval Air Development Center. Human engineering requirements manual for evolving systems (HERMES). Volume II. Prepared under Contract N62269-71-C-0348 for Naval Air Systems Command, Washington, D.C., June 1974.

Perkins, J.C., Maxey, G.C., Malone, T.B., Shenk, S.W., & Kirkpatrick, M. Human factors engineering. Part 1, Test procedures. Test Operations Procedure 1-2-610. Aberdeen Proving Ground, MD: U.S. Army Test and Evaluation Command, December 1977.

Perkins, J.C., Maxey, G.C., Malone, T.B., Shenk, S.W., & Kirkpatrick, M. Human factors engineering. Part II. HEDGE. Test Operations Procedure 1-2-610. Aberdeen Proving Ground, MD: U.S. Army Test and Evaluation Command, December 1977.

Price, H.E., Fiorello, M., Lowry, J.C., Smith, M.G., & Kidd, J.S. The contribution of human factors in military systems development: Methodological considerations. Prepared under Contract MDA 903-79-C-0553 for the U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA, July 1980.

Van Cott, H.P., & Kinkade, R.G. (Eds.). *Human engineering guide to equipment design*. Washington, D.C.: U.S. Government Printing Office, 1972.